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KINETICS OF CONTACT DRYING OF GEL FOR GLASS PRODUCTION

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The optimum regime for drying silicophosphate gel for glass production are selected. The kinetics of drying of gel is investigated.

The sol-gel method, which is one of the leading technologies in glass production, is acquiring extensive application. In addition to energy saving, this method makes it possible to obtain a wide range of high-purity homogeneous glasses. Glass articles in this case are produced both from continuous gel and from gel powder. The latter is more frequently used in synthesis of glass and glass-ceramic coatings for multiple purposes [1].

One of the stages of the technological process of glass synthesis is drying of gel. It is especially important to understand this process when using continuous gel. As soon as liquid is removed from gel in drying, the gel shrinks and stresses arise in it often disturb its continuity [2]. This problem can be solved by two-stage heat treatment with a long exposure at a low temperature. One can also introduce additives that control the drying process, for instance, formamide [3]. It is specified that drying by convection is used in all cases. As for the production of gel powder, the quantity of studies dedicated to its drying is very limited.

The purpose of our study was to select the optimum process of gel drying and to study its kinetics.

The process of drying by convection in our case is little effective, since the coefficient of heat transfer from the heat carrier to drying gel is relatively low and, furthermore, there is substantial entrainment of the solid phase from the drying zone when the material has low moisture. Such problems arise in spray drying of materials in dryers with bubbling and boiling layers. Gel formation in colloid solutions of the system $K_2O \cdot 3.5SiO_2 - (NH_4)HPO_4 - KOH - H_3BO_3$ – potassium aluminate produces a stable silicophosphate gel and a residual solution containing ions of K^+ , HPO_4^{2-} , and BO_3^{3-} [4]. It should be noted that filtration drying in this case would result in a loss of some of the technologically necessary components and cause a significant deviation in the composition of the resulting glass.

Consequently, the optimum solution, in our opinion, is contact drying, which has high intensity of heat supply to the

material and, accordingly, high intensity of moisture evaporation without loss of the dried material.

The mechanism of drying by conductance is described in detail in [5]. Its specific feature is a nonuniform and asymmetrical moisture distribution. The moisture content in the contact layer is minimal during the whole process, in the central layers it is maximum, and moisture of the material near the open surface is lower than in the middle layers but higher than at the contact surface. Such moisture distribution is the consequence of a special mechanism of material transfer in contact drying. The distinctive feature of the temperature field is that the temperature of any layer of the material keeps decreasing going from the contact layer toward the open surface.

The experiments were conducted according to a method developed by M. V. Lykov [6]. Changes in the gel moisture were found by weighing. A specific feature of this drying process was that heating was effected only from one side of the material. Heating lasted until reaching an equilibrium moisture W_{eq} for the particular conditions ($W_{eq} = \text{const}$).

Previous studies established that the temperature of gel drying should not exceed 110°C, since otherwise compounds with a high melting point are formed. The results of studies of gel drying kinetics are shown in Fig. 1. It can be seen that the kinetic curves have first (a constant rate) and second (a decreasing rates) periods. In the beginning of the process, short-term heating of the material is performed. The long first period is due to the fact that moisture evaporates only from the outer surface of the materials, i.e., in this case the drying process is identical to the process of evaporation from the surface of a liquid under free convection. Heat is supplied from the surface that is opposite to the gel layer. In such conditions the heating rate remains constant for a considerable time and the critical moisture W_{cr} is insignificant compared to the initial moisture of material W_0 . For the considered gel $W_0 \approx 1980\%$ and $W_{cr} \approx 50\%$ of absolutely dry material. The second period is short and the quantity of evaporated moisture is insignificant. This period stops when the gel reaches the equilibrium moisture $W_{eq} \approx 2\%$.

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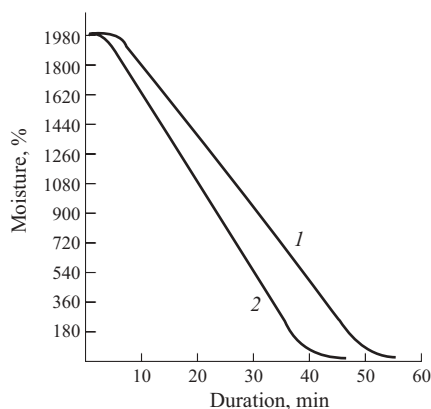


Fig. 1. Moisture variation in drying (gel layer thickness 6 mm) at temperatures of 70°C (1) and 90°C (2).

The results of studies of drying with various initial thickness of the gel layer indicated that the process kinetics substantially depends on this parameters (Fig. 2). Thus, at 70°C, as the gel layer thickness increases from 4 to 10 mm, the time of drying from the initial moisture level to the equilibrium grows from 42 to 100 min. At a temperature of 90°C, with increasing layer thickness the drying extends from 27 to 68 min.

Based on the obtained results the kinetic equation of gel drying is derived:

$$\tau = \frac{W_0}{v} - \frac{1}{0.0086v} [1 + 2.31 \log 0.0086 W_{eq}];$$

$$v = 50 + 0.71t - 9600\sigma,$$

where v is the drying rate in the first period, %/sec; τ is the time of gel drying, sec; t is the drying temperature, °C; σ is the thickness of the material layer, m.

It follows from the above equation that the dependence of the drying duration on the initial thickness of the gel layer is linear. This corroborates the statement that conductive drying of gel is similar to the evaporation process. This is evidenced by the results of studying the effect of temperature on drying duration. At 70°C, a gel layer 6 mm thick having the initial moisture level reaches the equilibrium moisture in 65 – 68 min, and at 90°C in 38 – 39 min.

Thus, gel-drying process by natural convection can be intensified by raising the temperature of the surface being dried and decreasing the initial thickness of the gel layer. However, the latter together with the invariable surface area of the phase contact leads to a decreased efficiency of the drying chamber. Therefore, the optimum drying conditions in industrial production are determined by the technical-economic parameters taking into account operating cost and capital cost.

The obtain results agree with the theory of heat- and mass- transfer in contact drying. However, there are certain specifics related to the physical state of the gel in drying. At

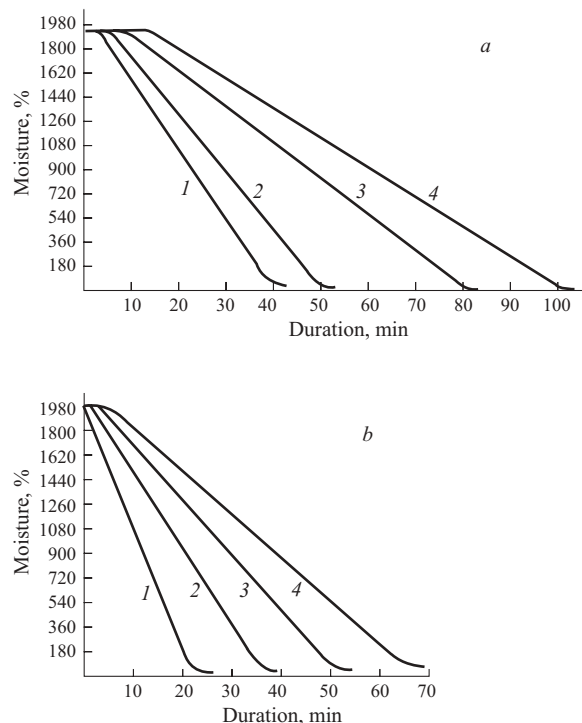


Fig. 2. Variation of moisture in drying at temperatures 70°C (a) and 90°C (b): 1, 2, 3, 4) gel layer thickness of 4, 6, 8, and 10 mm, respectively.

the beginning of drying, the porous structure is totally absent and evaporation proceeds from the liquid phase. It is only later that the concentration of the solid phase increases and a layer of material with a certain structure is formed.

Contact drying can be successfully implemented in roll dryers, which under optimum temperature conditions ensure not only a high rate of drying but can at the same time act as roll crushers to achieve homogeneity in the material dried.

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